'Globalization' and Vertical Structure

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Abstract.

This paper analyzes the effects of international openness on vertical integration decisions. A simple model is presented to represent the asset specificity problem at the heart of many industrial organization economists' analysis of vertical integration. It suggests that there is a kind of negative externality conferred by each vertical integration, by 'thinning' the market for inputs and thus worsening opportunism problems; thus, in equilibrium there tends to be too much of it. Further, vertical integration features a kind of strategic complementarity, which can lead to multiple equilibria in the outsourcing decision, thus providing a theory of different 'industrial systems' or 'industrial cultures' in *ex ante* identical countries. In addition, the country that gets stuck in a highly vertically integrated equilibrium suffers from lower efficiency. Greater international openness forces convergence in the degree of outsourcing across countries, and facilitates leaner, less integrated firms, thus providing a channel for welfare improvements from international openness that appears to be quite different from those that are familiar from the trade theory literature. This may be taken as one theory of 'outsourcing,' 'downsizing' and 'Japanization' as consequences of 'globalization.'

Much of topical economics implicitly or explicitly concerns changes in vertical integration decisions of industrial corporations. For example, the phenomenon of 'downsizing' often has a strong element of vertical divestiture[1]. Strong trends in 'outsourcing[2]' have been observed in recent years in many industrial sectors[3]. The differences in industrial 'systems' across countries, for example, between the U.S. and Japanese economies, have much to do with differences in vertical structure, with Japanese industry very much less integrated than its major trading partners[4].

All of these trends in vertical structure are at times claimed by various observers to have a strong relationship with international trade. Downsizing is held to be a response to increased foreign competition; the leaner organizational structure of Japanese industry allegedly gives it some advantages which have forced a partial 'Japanization' of some Western industries[5]. However, the logic in each case is far from clear, and there does not appear to be a body of

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[1]This was driven home emphatically by the brake workers' strike that crippled General Motors this past spring; the principal issue was GM's desire to outsource more of its brake production.

[2]Throughout this paper, the term 'outsourcing' will mean the provision of an input outside of the firm that will use it, not necessarily outside of the country in which it will be used. This appears to be a difference in usage between the industrial organization and trade theory literatures.

[3]See Gardner (1991) for the rise in outsourcing of data management by hospitals; *Bank Systems & Technology* (1991) on outsourcing of technology by banks; Buxbaum (1994) on the recent outsourcing of distribution services by GM; Bamford (1994) on the recent trend toward outsourcing of parts in the U.S. automotive sector; Bardi and Tracey (1991) on the move toward greater outsourcing of transport services across manufacturing; and *Economist* (1991) for an overview of the trend toward outsourcing in manufacturing in general.

[4]See Nishiguchi (1994) for an extensive analysis of the Japanese case; Morris (1991) and Gertler (1991) offer comparisons with North American industry. See also *Economist* (1991). Similar comments are sometimes made about small-firm industrialization in the 'Third Italy' of Emilia-Romagna and other regions; see Gertler (1991, pp. 380-5) for a review.

[5]See, for example, Gertler (1991).

theory within international economics to address these questions. Can a rise in openness affect the vertical structure of industry in a predictable way? If a 'leaner' organizational structure really is a lower cost way of procuring inputs[6], why would, say, an American auto firm wait until it is battered by competitors to implement it? Why would a profit-maximizing corporation not always choose to minimize costs? Further, does any of this have welfare implications?

This paper analyzes the effects of international openness on the vertical integration decision in an industry equilibrium, and suggests that openness can indeed have strong effects on vertical structure, and that this can have large welfare effects. A simple model is presented to represent the asset specificity problem at the heart of many industrial organization economists' analysis of vertical integration. It suggests that there is a kind of negative externality conferred by each vertical integration, by thinning the independent market; thus, in equilibrium there tends to be too much of it. This can lead to multiple equilibria in the outsourcing decision, thus providing a theory of different 'industrial systems' or 'industrial cultures' in *ex ante* identical countries despite profit maximizing behaviour. Nonetheless, globalization forces convergence in the degree of outsourcing across countries, and there is a presumption that it results in less vertical integration, thus providing a role for welfare improvements for international openness that appears to be quite different from those that are familiar from the trade theory literature.

The outlines of the argument are as follows. In this model, each of a number of final goods producers ('downstream firms,' or DSF's) tries to procure a specialized, indivisible input from a supplier (or 'upstream firm,' or USF). Each USF can produce one unit of specialized

[6]As argued forcefully by, among many others, Nishiguchi (1994) and *Economist* (1991). See also the recent consultant's report on the US auto industry cited in Maynard (1996), which pushed outsourcing very hard.

input. There are two possible procurement methods: 'arm's length,' or market, procurement; and 'integrated' procurement. In the former, the two firms form an understanding, perhaps through a verbal agreement, and come to terms on payment when the unit is ready. In the latter, some costly commitment technology is brought to bear, either a long-term contract or a merger between the two enterprises. This dichotomy is, of course, meant to capture some of the key issues in choosing the degree of vertical integration; in practice there is a continuum of such degrees available.

Because of the sunkeness of the cost of producing the input and its specialized nature, the USF knows that under the arm's length arrangement it is in danger of being 'held up' by the DSF and not recouping its costs *ex post*. Its only reassurance is that there may be alternative uses for the input beyond the DSF for which it is intended, which will give the USF bargaining power and allow it to demand a remunerative price. Thus, in the absence of a robust potential market for the input, the USF may judge the input to be an unremunerative product and abandon it. The alternative is the integrative arrangement, but this has its own disadvantages; either legal costs from negotiating and enforcing a contract or the costs of a merger and its attendant heightened 'governance costs.'

Thus, as argued in an extensive literature, each DSF/USF pair in the industry chooses between the two methods by trading off the 'hold-up' problem of arm's length trade against the 'governance costs' of the integrated solution[7]. However, three consequences of this reasoning are noted which are not much acknowledged in the existing literature. First, the feasibility of the arm's length system depends on the USF's prospects for recovering its sunk costs on the open

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[7]This language is most closely associated with Willamson (1971, 1989).

market; but these prospects are better the more of the other firms have chosen arm's length arrangements (or, the 'thicker' is the secondary market). The reason is that the equilibrium price received by an unintegrated supplier is determined by the input's *most attractive alternative use*, and the expected value of this is higher, the more alternative uses there are[8]. Since an unintegrated DSF is much more likely than an integrated one to be a potential alternative use for inputs from independent suppliers, it is thus natural that a rise in the number of unintegrated firms makes unintegrated supply more remunerative. This is Proposition 6 of the paper. There is thus a negative externality from vertical integration, making arm's length arrangements less feasible for others. For this same reason there is a 'strategic complementarity' in the vertical integration decision[9], so if the firms in the industry are sufficiently similar, there can be two equilibria: one with each firm choosing integration, and the other with all input suppliers remaining independent. One interpretation of this is that two otherwise identical countries can have completely different 'industrial cultures' or 'industrial systems' without in any way departing from strict assumptions of economic rationality or profit mazimization.

Second, an additional means of thickening the secondary market is to open up the economy to international trade. If two countries have similar industries facing the 'hold-up' problems described above, then lowering trade costs between them will make it easier for an input supplier to find an attractive alternative buyer abroad, thus strengthening its bargaining

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[8]Put differently, an input's price is determined by the second order-statistic of a finite sample; raising the sample size clearly raises its expected value.

[9]This sort of effect might also be present in the seminal analysis of Hart and Moore (1990) if only there was not an efficient industry-wide ownership contract worked out at time zero. In the present paper, ownership arrangements are worked out only bilaterally.

power *ex post* and making an arm's length arrangement more attractive. Thus, international trade can in principle lead to a substantial increase in the incidence of arm's length trade. Further, procurement systems across countries will tend to 'converge' with increased openness. There is, in addition, a sense in which increases in arm's length trade tend to be 'internationally contagious'.

Third, since a thickening of the market simply gives each firm more options in its procurement strategy, the effects of the opening up of trade on vertical structure are unambiguously efficiency enhancing. They thus provide an avenue for efficiency benefits of open trade that are completely separate from the well-understood avenues of increased specialization and competition, and which seem to be completely unacknowledged in the trade theory literature.

This paper builds on a well-established tradition in industrial organization which has not been put to much use in trade theory. The 'transactions cost' approach to vertical integration has been espoused by Williamson (1971, 1989) and Klein, Crawford and Alchian (1978). Although it is by no means the only important theory of vertical integration (see Perry (1989) for a survey), it has been shown to have a certain empirical explanatory power, as for example in Joskow (1987), Monteverde and Teece (1982), and Masten (1984), each of whom shows that in the data examined a greater level of 'integration' is predicted by a greater degree of asset specificity[10]. The incentive effects of different ownership structures in the context of specific investments and

[10]In the former study, which examines relationships between electric utilities and coal suppliers, the degree of integration is measured by the length of contract between the two firms. The second study looks at the make/buy decision among U.S. automobile producers, and the third in the aerospace industry.

incomplete contracts are studied in Grossman and Hart (1986), Hart and Moore (1990), and Bolton and Whinston (1993). Vertical integration emerges in some cases as the best response to the incentive problem. In the international trade literature, Spencer and Jones (1991, 1992) study the effects of vertical integration on strategic trade policy, without endogenizing the vertical integration decision.

Despite the richness of the literature on which it draws, the model used here has a number of novel features. It combines a simple formulation of the idea of technological serendipity with the finiteness of the set of firms in a given sector to provide a meaningful sense of the 'thickness' of a market[11]. It allows for endogenous choice of the degree of asset specificity by input providers, a decision which is affected by the integration decision and which in turn has its own effect on secondary market 'thickness.' In combining these elements, the model further shows how vertical integration by one pair of firms can confer a negative externality on the rest of the sector, thus pointing out that the analysis of the bargaining problem carried out by a number of pairs of firms in an industry can be qualitatively different from the analysis of a single pair of firms in isolation[12]. Although the model is itself quite special, these features in some form are likely to survive a number of kinds of generalization; this is discussed at the end.

Section 2 sets up the model; section 3 studies the determination of prices on the

[11]This concept of 'thickness' has a close relationship to the concept used by Telser (1981) to identify the advantages of organized futures markets.

[12]Another paper that focusses on horizontal interactions between firms in vertical integration decisions is Bolton and Whinston (1993). That model is built with two DSF's and one USF, and a random capacity for the USF so that the issue of 'supply assurance' plays a key role. A different kind of negative externality from vertical integration emerges in that case: The expected profit of the DSF left out of the arrangement falls, because it makes the integrated firm very aggressive in non-contractible investment.

independent market; section 4 derives equilibrium in the case of symmetric firms ('utter homogeneity'), which tends to give corner solutions; section 5 studies the case in which the firms are different enough that interior solutions are possible (the case of 'wide diversity'). Section 6 considers some alternative approaches.

2. The Model.

First we sketch the closed-economy version of the model; the open-economy version will then be straightforward. Consider an economy with an 'industrial' sector composed of n firms producing differentiated products, and an 'agricultural' sector, producing a homogeneous good under perfect competition. Suppose that all consumers have utility function[13] of the form $V(x_1, x_2, \ldots, x_n) + y$, where x_i denotes consumption of the ith 'industrial' good and y denotes consumption of the 'agricultural' good. The latter is the numeraire, and is produced with Ricardian technology with a marginal product of labor equal to unity, so that the wage is always unity as well. Each industrial good is produced with a fixed labor requirement and a constant marginal labor requirement; entry into that sector is prohibitively costly. Bertrand pricing determines the price and gross profit of each of the n firms; because of the separability of demand, these profits will be unaffected by any change in aggregate wealth.

Each firm in the industrial sector can reduce its fixed costs to some degree by procuring

[13]We will assume that the agents in the model maximize expected utility in cases in which there is a decision to be made under uncertainty. Given that, the form of the utility function implies risk neutrality with respect to income.

a specialized input[14]. These inputs can be tailor-made for the firm by entrepreneurs, who require K>0 units of labor to design and produce one unit of specialized input. This process takes two periods: The cost is incurred, irreversibly, in period 1, and the output is obtained in period 2. Call the input maker an upstream firm ('USF') and the firm interested in purchasing the input a 'downstream firm' ('DSF'). Each DSF can make use of at most one unit of specialized input, and each USF can produce only one unit.

Because of the lag between the costs and the output, the USF needs some reassurance that it will be paid remuneratively. To focus on the choice of organization forms, we assume that third-party verification problems preclude the possibility of purely contractual solutions[15]; see the discussion below. This leaves two possible solutions. The first is the 'integrated solution,' in which the two partners form a merger; this would involve internal 'governance' costs, denoted L. We will denote the integrated firm resulting from the merger of USF_i and DSF_i as IF_i. Under the second solution, the USF simply produces the unit and anticipates bringing it to open the market, hoping to fetch a high enough price *ex post* to recoup its costs. This we will call the 'unintegrated' or 'arm's length' solution[16], the use of an

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[14]It would be natural to allow such inputs to affect marginal costs as well, but the resulting price effects would be a tremendous source of additional complication, and are not necessary to get to the main points of the paper. Further, it would open up the possibility of vertical integration for the purpose of 'vertical foreclosure', a motive very different from the transactions cost motive that is the focus here. This is the subject of Hart and Tirole (1990), Ordover, et. al. (1990), and, in the international context, Spencer and Jones (1991).

[15]This is simply to keep the options for each firm pair down to two. A similar analysis could be performed with contracts as an additional option, provided that there were limitations or costs associated with them so that contractual solutions were not always optimal.

[16]The term is being used quite narrowly here. For a much richer conception of what arm's length relationships mean, see Crémer (1996).

'independent supplier,' or simply the 'market' solution.

'Governance' costs, or more broadly, managerial incentive costs of integration, are widely discussed in the economics literature[17]. We will have nothing new whatsoever to say about them here. For a particularly simple and extreme way of making them concrete, suppose that production of an input requires a U-asset and U-manager; production of the final good sold to consumers requires a D-asset and a D-manager. There are actions a U-manager needs to take from time to time to ensure that the asset will be useful, and there are actions a D-manager needs to take from time to time to ensure that the downstream operation will be profitable. Call these actions 'managerial care'. Suppose that the quality of the input is not verifiable to a third party, hence not contractible; thus, it is not feasible to write a contract conditioned on the delivery of a useful input[18]. Suppose that 'managerial care' is unobservable to anyone but the manager, and hence not contractible; further, it involves some effort and consequently some disutility to the manager. Thus, these actions will not be performed unless the manager owns the asset, and so each asset must be managed by its owner[19]. In the case of a merger, this implies that the same manager is managing two assets. We assume that there are diminishing returns to managerial attention, so that this causes an increase in fixed costs equal to $L>0$ if one asset is a U-asset and the other is a D-asset, and $M>0$ if they are both D-assets. We further assume that M is large

[17]See Williamson (1971, 1989) for extensive treatments; Calvo and Wellisz (1978) for a formal model; Grossman and Hart (1986) and Hart and Moore (1990) for treatments including this sort of incentive effect as part of a more general class.

[18]This precludes a simple contractual solution such as Nöldeke and Schmidt (1995). Complicated contractual revelation mechanisms such as in Rogerson (1992) may still be possible, but for our purposes we will suppose that they are impractical.

[19]Obviously, more generally the manager could own some fraction of the equity. The basic point is the same.

enough that horizontal integration is never profitable, simply so that we may focus on the issue of vertical integration.

In an initial period of bargaining, each DSF simultaneously arranges with a USF which of these two solutions will be pursued. Under the integrated solution, the two bargain *ex ante* and strike a deal, splitting the surplus net of contract costs L; the merged entity then designs and produces the input using the expected-profit-maximizing choice of technology. Under the arms' length solution, the two partners may meet and form a mutual understanding *ex ante*, perhaps through a verbal agreement, but there is no commitment on either side. The USF decides whether or not to advance; if it advances, it incurs the fixed cost K in period 1 and chooses the technology strategy to follow; in period 2 it receives the output and announces that it is accepting bids on it. The input is then sold to the high bidder, ending the game. The sequence is illustrated in Figure 1.

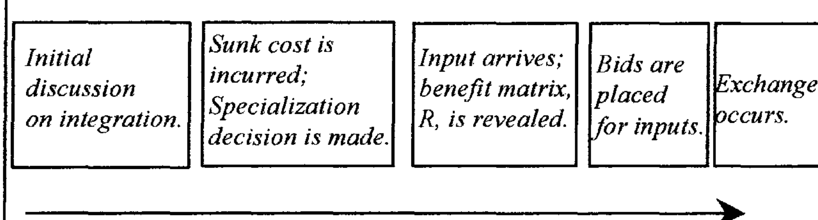

Figure 1. The Sequence of Events.

The USF is assumed to have two options in its design strategy: a strategy of 'maximal specialization' and a strategy of 'flexibility.' In the maximal specialization strategy, the input is designed in such close accordance with the peculiarities of the production process of the DSF in question that it would be useless for any other purpose. Define the cost reduction offered by the input designed for DSF i, when used by DSF j, as R_{ij}. We will refer to the matrix R as the 'benefit matrix.' Then under a strategy of maximal specialization, $R_{ij} = 0$ if $i \neq j$. We normalize R_{ii} in this case to unity. On the other hand, the design process could allow more room for the input to be compatible with other systems; since those other systems are likely to be less familiar to the USF, its uses with those systems are more likely to have a serendipitous nature[20] than the gains from the specialized technology strategy. These specialization decisions could be interpreted, for example, as choosing the degree of 'site specificity'[21] or 'design specificity'[22], to use Williamsonian terms. This is incorporated into the model as follows.

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[20]This implies a sort of uncertainty that can be extremely important in practice, especially in new or rapidly developing technologies. In a rapidly changing technological environment, the relative merits of alternative designs typically can not be identified at the design stage. Examples of *ex ante* uncertainty of this sort are legion; see Vincenti (1994) for an account of uncertainty in the 1930's about whether retractable landing gear or various alternatives would prove superior, and Numagami (1996) for an account of similar uncertainty in the 1970's about which design for digital watches would prevail.

[21]This is specificity resulting from physical proximity. For example, a coal-burning electric utility may become very specialized to a particular mine by locating close to the mine mouth; utilities have a wide variety of choice in such location decisions (Joskow, 1987). In the aerospace industry, there are large cost savings to be had by locating the computerized lathe for boring nose cones near the assembly plant in which the cones will be used; but once the lathe has been installed, it is extremely costly to move it. Thus, the location of the lathe is an important determinant of its specialization toward a particular assembler (Masten, 1984).

[22]This is specificity resulting from the design process *per se*. For example, a software designer may write a program to fit the peculiarities of a single firm's business, or may design it for the mass market as packaged software; the vast majority of the output of Japanese software houses fits the former category, and is never sold on an open market, in sharp contrast to the American system (Baba, *et. al.*, 1995). For another example, Melton Truck lines provides customized shipping services for Butler Manufacturing, which assembles pre-fab buildings for Wal-Mart in Mexico. The shipping jobs are complex and involve much coordination of different components and of border paperwork. Melton had a computerized system for this purpose, but it went the extra step of redesigning its own information management system to integrate it with Butler's system and provide a more effective service (Buxbaum, 1996). A notorious example of endogenously chosen asset specificity is the case of IBM in the 1970's redesigning its mainframe computer interfaces to make it difficult for non-IBM hard drives to be used with them (Brock, 1989).

Let the probability density function for R_{ii} under the flexible technology strategy be given by $h:[0, 1]\rightarrow\mathbb{R}$, with $\int x\, h(x)dx > K$. Let $g:[0, 1]\times[0, 1]\rightarrow\mathbb{R}$ be a non-negative valued function satisfying:

(i) $\int_0^1 g(y; x)dy = 1\ \forall x \in [0, 1]$;

(ii) $g(y; x) > 0$ for $x, y \in [0, 1]$ with $y<x$;

(iii) $g(y; x) = 0$ otherwise.

Thus, g is the probability density function, conditional on a variable x, for a random variable y on [0, 1] whose value never exceeds x. Now, if a USF has designed an input for DSF i, and has used the flexible technology strategy, we can speak of the *ex post* 'suitability' of the input for use with DSF j as measured by a random variable $x_{ij} \in [0, 1]$, where a value of 1 means complete suitability and a value of zero means complete unsuitability, and where $x_{i\cdot} = (x_{i1}, x_{i2}, \ldots, x_{in})$ has a density function ψ given by:

$$\psi(x_{i\cdot}) = h(x_{ii}) \prod_{j\neq i} g(x_{ij};\ x_{ii}).$$

Thus, the input is always most suitable for its intended use, but it may happen to have other uses that are almost as suitable. These suitabilities are realized as soon as the input is produced, and at that moment they become known to all.

This input then can offer potential cost reductions to the various DSF's as follows:

$$R_{ii} = x_{ii};$$

$$R_{ij} = \phi_i x_{ij} \text{ if } i \neq j,$$

where $\phi_i \in [0, 1]$ is an exogenous constant. Thus, the greatest possible cost reduction is to its intended DSF; this cost reduction is less than would it would have been under maximal specialization[23]; but if ϕ_i is not too small, the potential cost reductions for other DSF's might still be substantial. The parameter ϕ_i can be called USF i's "scope for flexibility." If it is close to zero, there is not much the USF can do to allow for alternative uses for its product. It will be a convenient parameter to vary in what follows.

An important consequence of these assumptions (particularly (iii) above) is that for either technology strategy:

(1) $$R_{ii} > R_{ij} \text{ with probability 1 for all i, where } j \neq i.$$

In short, under an arm's length arrangement, a USF designs an input, choosing specialized or flexible technology; once it is ready, the USF brings it to the market and sells it; after that, the game ends.

In the case of the open economy, there will be two countries which will be identical in every way. There will thus be 2n firms; those numbered 1 through n will be in country I and the following n will be in country II. The density function given above for the 'suitabilities' of

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[23]It would not change anything of interest to allow R_{ii} under maximal specialization to be random as well, provided that it was greater in expectation than R_{ii} under flexibility.

the n firms in one country will extend in the same way to the 'suitabilities' for the other country's firms as well. In order to focus on the vertical structure aspects of the situation and to make the point that the effects of openness in this model have nothing to do with well-understood effects through product-market competition, assume that the n final goods produced in each country are unattractive to consumers in the other, so that the final goods are effectively nontraded. Inputs, on the other hand, can be traded across the border at a cost of t. Thus, if $i \leq n$ and $j>n$, for an input i, $R_{ij} = \{\phi_i x_{ij} - t\}$ if it is designed with flexible technology, and $R_{ij} = -t$ if it is maximally specialized. Apart from these changes, the open-economy version of the model works in the same way as the closed-economy version.

3. *Ex post* price determination.

To solve the model, we work backward from the determination of prices and input allocations on the open market. For the moment assume a closed economy.

Once the n inputs have been produced, the matrix of R_{ij} values is known, and the various DSF's can send bids (simultaneously) to the various input makers. Let b_{ij} denote the bid made by buyer i for input j (for the moment allowing for the possibility that either firm i or firm j is integrated[24]; an integrated firm always have the option of selling its input or of placing a bid for another firm's input). The bids are made simultaneously and each represents a commitment to buy the stated input at the stated price, provided the seller accepts the bid. It will be convenient to define the vector of winning bids P by $P_i = \max_j\{b_{ji}\}$, which can also be called the vector of

[24]But not both; it would be meaningless for an integrated firm to bid for its own input.

equilibrium prices. Without loss of generality we restrict bids to be non-negative. In addition, since there is no meaningful difference between a bid of zero and no bid, we will without loss of generality require each potential buyer to place a bid of at least zero each input (except for an integrated firm's own good). Note that there is no contradiction between the impracticality of an *ex ante* contract to buy and the desirability of an *ex post* commitment to buy. Since quality is not contractible, an *ex ante* purchase contract would guarantee receipt of a worthless asset, by removing the incentive of the U-manager to take proper managerial care, as discussed above. However, once the input has been produced, that is not an issue.

Ignoring for parsimony costs incurred at earlier stages of the game, the payoff to an unintegrated DSF_i is given by the maximum of R_{ji} for $j \in S(i)$, minus $\sum_{j\in S(i)} b_{ij}$, where S(i) is the set of bids made by i that were accepted by the respective sellers. (Recall that i can make use of at most one unit of the input.) The payoff to an unintegrated USF_j is equal to $\max_i\{b_{ij}\}$; the USF simply accepts the high bid, perhaps randomizing over ties. The payoff to an integrated firm IF_i is the maximum of: max $(R_{ii}, \max_{j\in S(i)}\{R_{ji}\})$ minus $\sum_{j\in S(i)} b_{ij}$ (which it receives if IF_i does not accept a bid for its own asset); and $\max_{j\in S(i)}\{R_{ji}\}+\max_k\{b_{ki}\}$ minus $\sum_{j\in S(i)} b_{ij}$ (which it receives if it does).

To eliminate some technical nuisances, assume that the bids must be made in discrete units of currency; thus, for some $\varepsilon>0$, all bids must be an integer multiple of ε. The symbol $[x]^-$ will denote $\max\{y \mid y$ is an integer multiple of ε, and $y\leq x\}$. We will be interested only in what happens as ε becomes small. It is very important to keep in mind that the difference between P_i, the winning bid for any good, and the second-highest bid for that good, can never exceed ε in a Nash equilibrium.

We will be interested in Nash equilibria of this bidding game, in order to discuss subgame perfect equilibria of the full game. Propositions 1 through 5 provide a characterization. The first point to note about these Nash equilibria is that their outcome is *ex post* efficient.

Proposition 1. In any Nash equilibrium of the bidding game, with probability 1, if ε is small enough, no IF sells its input, and each independently produced input is sold to its originally intended buyer.

Proof. Suppose that in some equilibrium this is not so. In that case, denote z(i) as the input finally used by buyer i. In no Nash equilibrium will any buyer buy more than one input, or any input go unused, so the function z is invertible. Set $M = \{i \mid z(i) \neq i\}$, and note that $z(M) = M$. If $j \in M$, then buyer j chooses to purchase input z(j) rather than j; if j is unintegrated, she could have purchased j for $P_j + \varepsilon$, so we must have:

$$R_{jj} - P_j - \varepsilon \leq R_{z(j)j} - P_{z(j)}.$$

If $j \in M$ is integrated, she has sold input j for a price of P_j instead of using it herself, so:

$$R_{jj} \leq R_{z(j)j} - P_{z(j)} + P_j, \text{ or}$$

$$R_{jj} - P_j \leq R_{z(j)j} - P_{z(j)}.$$

Thus, if we denote by ñ the number of independent firms in M, we must have:

$$\Sigma_{j \in M}[R_{jj} - P_j] - \tilde{n}\varepsilon \leq \Sigma_{j \in M}[R_{z(j)j} - P_{z(j)}].$$

Since $M = z(M)$, this implies:

$$\Sigma_{j\in M}[R_{jj}]-\tilde{n}\varepsilon \leq \Sigma_{j\in M}[R_{z(j)j}] = \Sigma_{j\in M}[R_{j\ z(j)}],$$

where the last equality follows from the invertibility of z. From (1), as ε becomes small this must become false. **QED.**

This considerably simplifies the problem. It allows us to write the condition for a Nash equilibrium as the condition that for each i and j, buyer j prefers to buy the input designed for her at price P_j rather than outbid buyer i for input i:

$$R_{jj}-P_j \geq R_{ij}-P_i-\varepsilon \text{ for all } i^{25},$$

which implies:

(2) $$P_i \geq \max_j \{\max(R_{ij}-R_{jj}+P_j,\ 0)\}-\varepsilon.$$

Since it shows that integrated firms will not engage in any purchase or sale in the market stage, Proposition 1 also implies an immediate corollary:

Proposition 2. In a subgame perfect equilibrium, any integrated firm will choose the maximally specialized technology.

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[25]If j is integrated, this condition is unchanged. The payoff from keeping input j is R_{jj}; the payoff from selling it and buying another is $P_j-(P_i+\varepsilon)+R_{ij}$. The latter must not exceed the former, and this is the stated inequality.

Any other choice would reduce $E[R_{ii}]$ without having any other effect on IF_i's profits. We obtain a further characteristic of equilibrium by eliminating weakly dominated strategies from the strategy set, thus leaving only 'perfect' equilibria. In the context of this bidding game, this set of strategies includes any bid by any buyer i for any input j such that $b_{ij}>R_{ji}$, since lowering such a bid to $[R_{ji}]^-$ will either raise i's profit or have no effect. Focussing on equilibria satisfying this refinement immediately tells us that if good i is maximally specialized, $b_{ji}=0$ for $j\neq i$, since then $R_{ij}= 0$ for $j\neq i$. Thus:

Proposition 3. As $\varepsilon \rightarrow 0$, the equilibrium price of any maximally specialized good in a perfect equilibrium goes to zero. In particular, in any perfect equilibrium of the full game, the equilibrium price of any input produced by an integrated firm goes to zero.

It is therefore obvious that an unintegrated supplier would never choose the maximally specialized technology. As a consequence of Propositions 2 and 3, we see that an input is produced with flexible technology if and only if it is produced by an unintegrated supplier. There is an exact correspondence between ownership structure and technology choice.

These conditions narrow the outcomes quite a bit; however, there are in general multiple equilibria of the bidding game even after eliminating weakly dominated strategies. As an illustration, consider the case in which n = 2, no firm is integrated, input 1 would offer 10 units of cost reduction to DSF_1 and 9 to DSF_2, and input 2 would offer 5 units of cost reduction to DSF_1 but 7 to DSF_2. Suppose that all integers are divisible by ε. The bidding game here has a range of perfect equilibria. One example is: $[b_{11}, b_{12}, b_{21}, b_{22}] = [9, 5\text{-}\varepsilon, 9\text{-}\varepsilon, 5]$; each DSF bids for the other's designated input just ε below the gross cost reduction that input would give her, and for her own designated input the minimum bid required to acquire it, ε plus the competing bid[26]. We might call this the 'high-price' equilibrium. By contrast, $[2+\varepsilon, 0, 2, \varepsilon]$ is also an equilibrium for the same benefit matrix. We might call this the 'low-price' equilibrium. We need to make some sort of equilibrium selection, since the difference in payoffs between these two is enormous.

Here the selection will be based on the following odd feature of the high-price equilibrium. Consider DSF_1's profit on its successful bid for input 1, valued at 1, compared with its profit should its losing bid for input 2 be accepted instead. That hypothetical profit would be $(5 - [5-\varepsilon]) = \varepsilon$. Clearly, it would strictly prefer to lose its bid for good 2. Similarly, DSF_2 earns $(7 - 5) = 2$ on its winning bid for input 2, but would earn ε on its bid for input 1 if that were accepted instead, and so DSF_2 strictly prefers to lose its bid for good 1. The natural question is: Why, then, would it place that bid? Of course, in equilibrium it does not matter, since it does lose the bid after all, but it seems to be a weak reed to support a high-price equilibrium solely with losing bids placed by firms that would have no interest in winning them. By contrast, in the low-price equilibrium, DSF_2 makes a profit of $(7-\varepsilon)$ on its winning bid, and would make a profit of 7 on its losing bid for input 1 if that were accepted instead; DSF_1 strictly prefers to win its own input and does not bid anything for the other input. We will restrict attention to equilibria in which the only non-zero losing bids a firm ever places are bids that would be at

[26]It is easy to check that this is a Nash equilibrium. DSF_1 buys input 1 at a price of 9, receiving a profit of $(10-9) = 1$; the best alternative move would be to buy input 2 instead, for which the lowest price would be $5+\varepsilon$. This would give a profit of $-\varepsilon$, so the deviation would be unprofitable. Analogous reasoning for DSF_2 shows that its bid is optimal given DSF_1's.

least as profitable as its winning bid, in the odd event that that bid were accepted instead. This is summarized by requiring that for any buyer j and input i, either:

$$R_{ij} - b_{ji} \geq R_{jj} - b_{jj},$$

or $b_{ji} = 0$. We might call this the "only desirable bids" (ODB) condition. It can be written this way:

$$b_{ji} \leq \max\,(R_{ij}\text{-}R_{jj}\text{+}b_{jj},\ 0) = \max\,(R_{ij}\text{-}R_{jj}\text{+}P_j,\ 0),$$

so that

$$\text{(3)} \qquad P_i = b_{ii} \leq \max_{j\neq i}\{b_{ji}\}\text{+}\varepsilon \leq \max_j\ \{\max\,(R_{ij}\text{-}R_{jj}\text{+}P_j,\ 0)\}\text{+}\varepsilon.$$

Putting this together with the Nash equilibrium condition (2) tells us that in the limit as $\varepsilon \rightarrow 0$, any ODB equilibrium price vector P can be written as[27]:

$$\text{(4)} \qquad P = T_R(P),$$

where for any benefit matrix R, $T_R(\cdot)$ is an operator on $\mathbb{R}^n_+$ such that for any n-vector q, the i^{th} component of $T_R(q)$ is:

$$[T_R(q)]_i = \max_j\ \{\max\,(R_{ij}\text{-}R_{jj}\text{+}q_j,\ 0)\}.$$

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[27]From this point on, we will look only at the limit as $\varepsilon \rightarrow 0$, so this qualification should be understood in the statement of all subsequent propositions.

Equation (4) has a simple intuitive meaning. The term R_{ij}-R_{jj}+P_j can be read as the most that buyer j would be willing to pay for input i, given that the price of input j is P_j. If R_{ij}>R_{jj}, input i would do a better job for buyer j than j's own custom-made input, and j would be willing to bid more for it as a result.

Note that there is no contradiction between the fact that $R_{ii} > R_{ij}$ whenever i≠j and the possibility that R_{ij} might exceed R_{jj}. The distinction between the two is much like the difference between absolute and comparative advantage. The statement that $R_{ii} > R_{ij}$ for all firms implies that the most efficient allocation of inputs is to place each one in the DSF for which it was designed, and is much like saying that each input's *comparative* advantage is with its intended use. However, the statement that $R_{ij} > R_{jj}$ means that disregarding its opportunity cost, input i would produce a larger benefit to DSF_j than the input designed for DSF_j, and is much like saying that input i has an *absolute* advantage over input j in serving DSF_j. This is what might give USF_i a possibility to enjoy a remunerative price: the higher its input's absolute advantage in use j, the more buyer j will be eager to bid for it, even in the low-price equilibrium. Figure 2 illustrates a case in which each of three firms' tailor-made inputs has a comparative advantage in use for that firm, but input 3 has an absolute advantage in all of them. This distinction is key to the logic of the model: The workings of the bidding game can be summarized by suggesting that *comparative advantage determines the allocation of inputs, but absolute advantage determines the distribution*

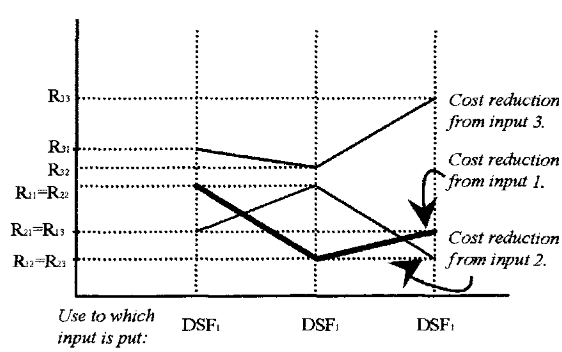

Figure 2. A Sample Pattern of Cost Reductions.

of income.

Equation (4) further tells us that in any ODB equilibrium, the price of any good, if it is not zero, is determined by a 'chain of absolute advantage.' More precisely, for an equilibrium price vector P and for any i, define $\lambda(i; P) = \text{argmax}_{j \neq i} \{R_{ij}-R_{jj}+P_j\}$ if this maximum is non-negative[28], and set $\lambda(i; P) = i$ otherwise. We can say that $\lambda(i; P)$ then identifies the 'runner-up bidder' for input i in equilibrium, with $\lambda(i; P) = i$ if and only if $P_i = 0$. We then have:

Proposition 4. For any good i in any ODB equilibrium with price vector P, with probability 1, either $P_i = 0$ or there is an integer $k \leq n$ such that if we define $z(1) = i$; $z(2) = \lambda(i; P)$; $z(3) = \lambda(z(2); P)$, and so on, then:

(i) $P_{z(k)} = 0$, but $P_{z(m)} > 0$ for $m<k$;

(ii) $z(m) \neq z(m')$ if $m < m' \leq k$; and

(iii) $P_i = \sum_{m=1,..,k-1}[R_{z(m)z(m+1)} - R_{z(m+1)z(m+1)}]$.

In other words, the price of good i is found up by adding of a sum of absolute advantages along a chain of runner-up bidders until we hit a buyer whose own input bears a zero price.

Proof: See Appendix.

The way this works in the above simple numerical example is clear. There, even though

[28]The j so defined will be unique with probability 1, so we will treat it as unique here.

DSF_2 can obtain its own designated input virtually for free, it still is interested in bidding for input 1, since that input offers an absolute advantage of (9-7) = 2 in use by DSF_2. Thus, DSF_2 bids 2 for that other input. This is what forces DSF_1 to bid slightly above 2 for input 1. At the same time, since good 2 offers no absolute advantage to DSF_1, DSF_1 bids nothing for it. This is what allows DSF_2 to get it for free.

Finally, it is not difficult to show that the equilibrium can be simply calculated:

Proposition 5. There is a unique ODB equilibrium, and it is given by $P = [T_R]^{n-1}(\mathbf{0})$, where $\mathbf{0}$ is a vector of n zeroes, and $[T_R]^{n-1}$ denotes application of the T_R operator n-1 times in succession.
Proof: See Appendix.

The ODB equilibrium has attractive properties aside from those mentioned above[29], but for the sake of robustness the consequences of making a different equilibrium selection will be discussed in section 6.

Now we can discuss the equilibria of the full model. We do this under two contrasting assumptions about the way the scope for flexibility differs across firms; first, the assumption that it does not vary at all (the case of 'utter homogeneity'), and then the assumption that it varies

[29]For example, it can be shown using results from Gül and Stacchetti (1996) that it is equal to the marginal social value vector for the various inputs, in the sense that if P is the ODB price vector, and if an additional copy of input i was added to the system (so that now there are n+1 inputs for n uses); and if the enhanced set of inputs were reallocated in a socially optimal way, the increase in social surplus that would result is P_i. This is intuitive: The extra copy of input i would go to the use in which it would generate the greatest social cost savings, $\lambda(i, P)$; there it would reduce gross costs by $R_{i\,\lambda(i;P)} - R_{\lambda(i;P)\,\lambda(i;P)}$, and liberate input $\lambda(i;P)$ for other uses; this input would then be moved to $\lambda^2(i;P)$, where it is most needed, and so on.

greatly, in a sense to be made precise later (the case of 'wide diversity').

4. Industry Equilibrium: The case of utter homogeneity.

Suppose that ϕ_i takes on the same value for all i, and denote this common value by ϕ. An equilibrium can be constructed by working backward from the bidding game. For the moment assume a closed economy.

It has already been noted that if in the initial bargaining an integrated solution is selected, the maximally specialized technology strategy will be pursued, otherwise flexible technology will be used if the input is produced at all. Let F denote the set of USF's using flexible technology, and also the set of DSF's using independent suppliers. Note further that no firm will enter a non-zero bid for an integrated firm's input; and if j is integrated, $(R_{ij}-R_{jj}+P_j) = (R_{ij}-1+0) < 0$, so that an integrated firm will not enter a non-zero bid for any other firm's input. Thus, $P_i = 0$ for any integrated firm's input, and the prices of the non-integrated firm's input is affected only by the presence of the other non-integrated firms. Under utter homogeneity, this means that we can write:

$$\mu(\phi, n_F) \equiv E[P_i],$$

for any non-integrated firm i, where F is the set of non-integrated (hence, flexible-technology) firms, n_F is the number of firms in this set, and the expectation is taken with respect to the realizations of the random x_{ij} from which the benefit matrix is derived. The dependence of μ on

n_F is the sense in which the 'thickness' of the independent market for inputs matters.

Proposition 6. The function μ is increasing in n_F.

Proof: It is sufficient to compare the case in which firm n is integrated with the case in which it is unintegrated. Thus, consider two cost matrices, R and R′. Suppose that $R_{ij} = R'_{ij}$ except that $R_{nn}= 1$; $R_{nj}= 0$ if $j\neq n$; $1>R'_{nn}>R'_{nj}>0$ for $j\neq n$. Then it is easy to confirm through element-by-element comparisons that: (i) $T_{R'}(\mathbf{0})\geq T_R(\mathbf{0})$; (ii) if $q'\geq q$, then $T_{R'}(q')\geq T_R(q)$; and therefore (iii) if $[T_{R'}]^k(\mathbf{0})\geq[T_R]^k(\mathbf{0})$, then $[T_{R'}]^{k+1}(\mathbf{0})\geq[T_R]^{k+1}(\mathbf{0})$. Using Proposition 5, the rest is then just induction. **QED.**

This is the key to the argument of the paper. It may seem curious that a rise in n_F, effectively the addition of one buyer and one seller to the open market, should lead to a rise in the expected prices of the various inputs. The explanation is that the price of an input is determined by the most attractive alternative use, because that determines what the value of the runner-up bid will be. Adding one more buyer and one more seller may either result in a new bid for an existing input that is higher than the incumbent bids, thus raising the equilibrium price of that input; or have no effect. There is no way it can lower the price of an input. This may be illustrated with an extension of the earlier numerical example. Suppose that to that system of two independent inputs, we add a third, and that the three offer cost reductions as in the following table:

Fixed cost reduction to:	DSF_1.	DSF_2.	DSF_3.
Input 1.	10	9	1
Input 2.	5	7	3
Input 3.	1	1	4

The equilibrium prices are now (2, 0, 0). The prices of the incumbent goods have not changed, because the new good does not have an absolute advantage in any other use, nor do the incumbent inputs have an absolute advantage in good 3. However, if R_{33} had turned out to be 2 instead of 4, input 2 would have an absolute advantage in use 3 given by (3-2) = 1. Thus, DSF_3 would place a bid of 1 for input 2. This would push the price of input 2 up, at the same time raising 2's bid for input 1, since with input 2 now more expensive, input 1 is now even more attractive to DSF_2. DSF_2's bid for 1 goes up to $(R_{12}-R_{22}+P_2) = (9-7+1) = 3$. Thus, the new price vector is (3, 1, 0). The example illustrates how adding to the independent market is a kind of one-sided bet to the incumbent sellers: If the new independent buyer turns out to be uninterested in the incumbents, it makes no difference to them, but if it turns out to be interested, it pushes their prices up -- possibly through a cascading chain reaction along the chain of absolute advantage[30].

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[30]The importance of 'serendipity,' in the form of *ex ante* uncertainty about the R_{ij}'s should by now be clear. If, for a given choice of technology, we removed the uncertainty and replaced the elements of the benefit matrix with their *ex ante* means (so that $R_{ii} = \int x\, h(x)dx \equiv \rho$ and $R_{ij} = \int y\, g(y; x)h(x)dx\, dy \equiv \sigma$ for flexible firms), then no flexible input would offer an absolute advantage in any alternative use (since $\rho>\sigma$), and so no flexibly produced input would ever have a positive price. In this sense, *uncertainty about the outcome of*

The arm's length method will produce an input for DSF_i provided that USF_i expects to receive a high enough price *ex post* to recoup its sunk costs, or in other words, if $\mu(\phi, n_F) \geq K$ will hold with $i \in F$. Since μ is increasing in n_F, for a given value of ϕ, this will clearly be true provided that n_F exceeds some threshold $\bar{n}$ with $i \in F$, defined by $\bar{n} = \min \{ m \mid \mu(\phi, m) \geq K \}$. Thus, in the initial bargaining between USF_i and DSF_i, if $(\bar{n}$-1) or more other firms are expected to use arm's length arrangements, it will be feasible for DSF_i to use an arm's length arrangement as well. Otherwise, the only procurement option will be integration.

If the two firms integrate, the net cost reduction will be R_{ii}-L-K = 1-L-K because the integrated entity will use the maximally specialized technology. The net cost reduction from arm's length trade will be $E[x_{ii}]$-K. There is clearly a trade-off between the two: The integrated solution allows for the greatest technological cost reduction (since $E[x_{ii}]<1$), but imposes additional 'governance' costs L. Since integration is always an option, if the former outweighs the latter, there is nothing to discuss: We will always observe integration. The problem becomes interesting only if this is not so, and so we assume:

$$\text{(A1)} \qquad 1-E[x_{ii}] < L.$$

Thus, if it is feasible, the surplus from arm's length trade will always exceed the surplus from integration, and an arm's length arrangement will be the outcome of *ex ante* negotiations.

We can now speak of a Nash equilibrium in vertical structure. For any pair of firms i, if $\bar{n}$-1 other pairs are expected to use an arm's length arrangement, i will do so as well; but if

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technological development is what makes non-integrated production possible.

fewer than $\bar{n}$-1 are expected to integrate, i will integrate. It is immediate that this implies that the only possible equilibria are $n_F = 0$ and $n_F = n$: complete integration of the sector and universal use of independent suppliers.

Proposition 7. In a small closed economy ($n<\bar{n}$) with utter homogeneity of firms, the only equilibrium is complete vertical integration. In a large economy ($n\geq\bar{n}$), there are two equilibria: Complete integration and universal use of independent suppliers.

This highlights a point about the transactions-cost approach that does not appear to be widely acknowledged: It implies a kind of strategic complementarity in integration decisions. A larger number of firms using independent supply implies a wider use of flexible technology, hence a thicker secondary market, and thus makes it more attractive for any given firm to use independent supply. An immediate consequence is that two otherwise identical economies in isolation from each other can evolve completely different 'industrial systems' or 'industrial cultures', one strictly more efficient than the other. This outcome bears a resemblance to descriptions of national differences in sourcing strategies and particularly the contrast between the highly integrated 'fordist' model of Western economies and the striking predominance of outsourcing in Japanese industry as compared to other economies, which many observers appear to regard as an inherently more efficient sourcing system (for example, Nishiguchi (1994), Gertler (1991), and *The Economist* (1991)). In addition, it carries with it the implication that despite this inefficiency of the integrated outcome, no single firm in the vertically integrated economy would wish to switch procurement methods: The secondary market would be too thin to make it practical.

The open economy version of this model is then straightforward to analyze. We must now write the unintegrated USF's expected revenue as $\mu(\phi, t, n_F, n_{F'})$, where $n_{F'}$ is the number of unintegrated firms in the other country, to take account of the fact that R_{ij} is a decreasing function of t if $i \leq n$ and $j > n$ or vice versa. The parameter 't' could be either a tariff or transport costs, or possibly extra transactions costs imposed by cross-border regulation. Whatever the interpretation, we will call 'globalization' a reduction in 't,' where the initial value will be taken as a sufficiently high value that in effect the two economies act as if closed. If we define an economy as 'small', 'medium' or 'large' depending on whether $n < \bar{n}/2$, $\bar{n}/2 < n < \bar{n}$, or $n > \bar{n}$, then it is clear that for two small economies, globalization will have no effect on vertical structure (since whatever value t takes, the only equilibrium will be integration). However, in the other two cases it can have significant effects:

Proposition 8. In the case of utter homogeneity of firms, a sufficient globalization between medium-sized countries will make the more efficient arm's length equilibrium possible in both economies. It would not be possible in either economy without globalization.

Clearly, if t falls by enough, the above reasoning for the closed economy case will apply to the combined economies of the two countries. Thus, the finding that the only equilibria involved all firms acting in the same way applies as well:

Proposition 9. Whatever the size of the economies concerned, in the case of utter homogeneity of firms, with a sufficient globalization any equilibrium will involve complete convergence of the vertical structure of the two economies.

5. Industry Equilibrium: The case of wide diversity.

The above homogeneity assumption ought not to be taken too literally, since in practice it certainly is not true that every single business enterprise within an industry in a given country does business in exactly the same way. The reason is plausibly that there are some *ex ante* differences between firms, for example in their scope for flexibility. Thus, suppose that within each country each firm has a different value for ϕ_i. Let the firms in each country be ordered in descending order of ϕ_i. Again, begin with the closed economy case. We can write the expected payoff of an unintegrated supplier i as:

$$\mu(\phi_i, F) \equiv E[P_i].$$

This time, naturally, the *ex ante* payoff can differ between firms, and further not only the number but also the identities of the firms in the unintegrated set F will matter. Not surprisingly, the expected revenues of an unintegrated firm with a large scope for flexibility will be greater, *ceteris paribus*, than those for a firm with less flexibility. This can be seen by considering two firms, i and j, with $\phi_i = \phi_j$ initially, and noting how their payoffs change with an increase in ϕ_i.

Proposition 10. If i, j $\in$ F and i$\neq$j, then:

$$\frac{\partial E[P_i]}{\partial \phi_i} > \frac{\partial E[P_j]}{\partial \phi_i} > 0.$$

Proof: See Appendix.

Because the payoff to a higher ϕ_i independent USF will be greater than that of a lower ϕ_i USF, in any Nash equilibrium pattern of vertical structure, F must be composed of an unbroken sequence of firms from i=1 up to and including a threshold firm, say ñ, with $\mu(\phi_{\tilde{n}}, \{1,..., \tilde{n}\}) \geq K$ but $\mu(\phi_{\tilde{n}+1}, \{1,..., \tilde{n}+1\}) \leq K$. If $\mu^*(i) \equiv \mu(\phi_i, \{1,..., i\})$ is a strictly decreasing function of i, there is only one such ñ, and hence one equilibrium. This will clearly be so if ϕ_i falls sufficiently fast in i; here we assume that it does.

In the open economy case, USF$_i$'s expected revenue can be written $\mu(\phi_i, t, \{1,...\tilde{n}), \{1,...\tilde{n}'\})$, where ñ′ is the number of unintegrated firms in country II. For any t and ñ′, we can find the value of ñ consistent with equilibrium in country I. This gives a kind of country I 'reaction function' (abusing the term somewhat, since each firm pair in country I acts independently). Since a rise in ñ′ shifts the function μ up, this 'reaction function' necessarily slopes upward. Once again, strategic complementarity is in evidence in integration decisions. The same argument works for country II, and the two 'reaction functions' can be combined to find the equilibrium number of independent suppliers (ñ, ñ′) in the two countries. This is demonstrated in Figure 3, under the assumption:

(A2) $\mu(\phi_{i+1}; \{1,..., i+1\}, \{n+1,..., n+i'+1\}) \leq \mu(\phi_i; \{1,..., i\}, \{n+1,...,n+i'\})$

for all i, $i' < n$. This is the meaning of the assumption of 'wide diversity' between business firms. It implies that $\mu(\phi_i, \{1,..., i+1\}, \{n+1,..., \tilde{n}\})$ slopes downward in i, but further that each country's 'reaction function' never has a slope exceeding unity. This is equivalent to so-called 'stability assumptions' in simple oligopoly models.

Globalization unambiguously raises the incidence of independent supply in both countries, moving the world economy from point A to point B. This leads to a welfare improvement in both countries, because of A1.

Finally, note that under these conditions there is a sense in which outsourcing practices are internationally 'contagious.' If country II undergoes an exogenous change in technology so that each of its firms now has a greater scope for specialization (and so ϕ_i goes up for each of its firms), that will lead to a rise in its incidence of outsourcing for any given country I outcome. This can be represented as the broken curve in Figure 3, a shift of country II's 'reaction function.' But this of course stimulates a greater use of outsourcing in country I, and this reinforces the additional popularity of outsourcing in country II. Thus, both countries depend to a greater extent than before on independent suppliers, with the final outcome at point C. It should be remembered that at no time does any trade occur between these two countries at all: A change in contracting behaviour in one country affects the other through the thickness of the implicit

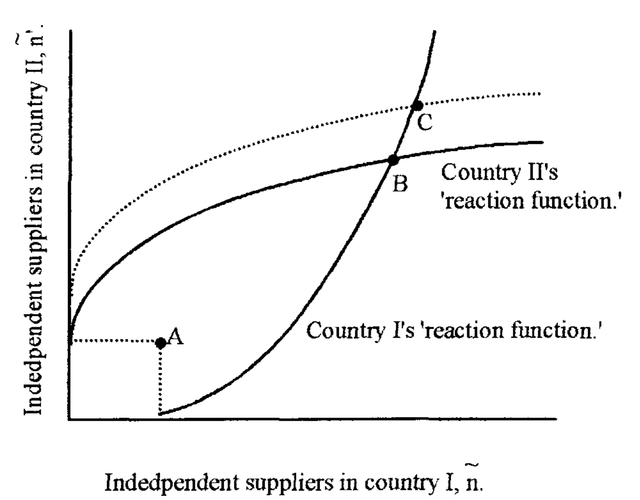

Figure 3: International Equilibrium Under 'Wide Diversity.'

secondary market for inputs, thus changing bargaining power. Nonetheless, the process of 'globalization' has had substantial real effects in both countries.

6. Possible Extensions.

The object here has been to show that some simple ideas from industrial organization can readily to brought into an international context, and offer some promise as a framework for analyzing the relationship between international openness and vertical structure. In particular, the central point has been the role of a rise in market 'thickness' resulting from greater openness. To allow for greater focus on this one effect, the model has been extremely simplified. Here we will discuss a few directions in which assumptions could be relaxed or altered.

First, there is no particular reason to cling in general to the two extremes of 'utter homogeneity' and 'wide diversity.' Once those two cases are understood, it is straightforward to extend the analysis to any intermediate case. The key result of strategic complementarity in integration decisions, and the finding that the set of non-integrated firms will be the ones with the highest values of ϕ_i, will still hold. A case of particular interest would be the case in which the function $\mu^*(i) = \mu(\phi_i; \{1,...,i\})$ has a value greater than K for i=1, falls below K as i rises, then crosses K twice more as i rises to n. In this case, we have 'highly integrated' and 'highly unintegrated' equilibria, neither of which is a corner. Thus, there is no reason in general to insist that multiple equilibria must go hand in hand with a corner solution.

Second, although the appeal of the low-price equilibrium of the price game compared to the other equilibria seems strong, some may be interested in the consequences of other equilibria.

The only other one that seems at all focal is the 'high-price' equilibrium. In this equilibrium (in the limit as $\varepsilon \to 0$), the price of input i is given by $P_i = \max_{j \neq i}\{R_{ij}\}$, or, in the most naive sense, the value of its best alternative use[31]. It is straightforward that this reproduces every qualitative result, *mutatis mutandis*, in Propositions 2, 3, 6, 8, 9, and 10 (with the exception that a rise in ϕ_i will now increase only the price of input i). Thus, the main economic consequences of the analysis will be unchanged. However, note that some odd features will be present; aside from those already mentioned, note that even integrated firms, with their maximally specialized inputs in hand, will bid positive sums for other firm's inputs, in which they have no interest.

More broadly, one may wish to depart from the Bertrand-type price determination structure. It may be of interest to examine Walrasian prices, for example. This turns out not to give any greater generality, however. Because the First Welfare Theorem will be satisfied (*ex post*) by such an equilibrium, the allocation of the inputs will be the same as they are in the bidding equilibrium studied above. Further, using this fact, it is easy to show that the set of Walrasian price vectors, and the set of price vectors supportable by Nash equilibria of the above price game, are one and the same. Using results from Gül and Stacchetti (1996), it is easy to show that the lowest-price Walrasian equilibrium is given by the ODB price vector studied in the text.

It may be of interest to examine bargaining versions of the model. Perhaps the simplest way of formulating bargaining in this setting is to allow DSF_i and USF_i to engage in Nash bargaining once the input is ready; if the bargaining breaks down, they walk away from the table

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[31]This is supported as a Nash equilibrium by $b_{ij} = [R_{ji}]^-$ if $j \neq i$ and $b_{ii} = \max_{j \neq i}\{b_{ji}\}+\varepsilon$. As noted above, this involves firms making positive, but losing, bids which they strictly prefer to lose.

irrevocably and seek other partners; if they find willing partners, they follow Nash bargaining with them and the game ends. The payoffs from the second (potential) stage of bargaining form the threat point of the first stage of bargaining. The Appendix shows that this framework provides conclusions qualitatively identical to the main ones of the text. Extensions to other bargaining frameworks, including non-cooperative approaches, may be of some interest, as may approaches that involve the Shapley value.

The relaxation of conditions ensuring condition (1) may be of some interest. If there is a possibility that some input other than the one designed for DSF_i has its socially most efficient use with DSF_i, then we may see 'downsizing' at some times taking the form of 'firing' one's original input supplier (in other words, not purchasing its input). Thus, although welfare enhancing, globalization may fail to be *ex post* Pareto improving. Further, in such a formulation there would be a second interesting source of welfare benefit from market 'thickening': It would raise the expected value of a match. In the current model, the expected surplus generated by an equilibrium match between a USF and a DSF is always $E[R_{ii}]$; market thickening affects the *distribution* of this surplus between the two partners, but not the *level* of this surplus. However, if (1) does not hold, both effects will be at work, possibly accentuating the strategic complementarity of integration decisions.

A further generalization that may be of some interest is the allowance for a wider set of organizational choices. Aside from complete integration and a pure market approach, procurement in practice involves partial equity control, quasi-integration, contracts of varying lengths, forms, and complexities; and reputational solutions. It is speculated here that in a richer model with some more such options specified, each with its own peculiar costs and constraints, we may see a tendency for a thicker market to lead to relatively less integrated forms within partially integrated firms, as well as a reduction in the number of totally integrated firms. In addition, it could be quite interesting to inquire how the form of optimal procurement contracts, for that portion of firms using them, is affected by the sort of general equilibrium effects outlined here. However, this is beyond the scope of this paper.

Appendix.

Proof of Proposition 4.

First, it is simple to see that we can find a value of k satisfying (i) and (ii). Since there are a finite number of inputs, for k large enough (ii) must be violated; choose the largest k such that it is not. For this k, z(j) = z(k+1) for some j≤k. Suppose that j<k. Then ($P_{z(j)}$, $P_{z(j+1)}$,...,$P_{z(k)}$) are all strictly positive (since λ(j; P) = j if and only if $P_j = 0$). Thus, from (4),

$$P_{z(j)} = \Sigma_{m=z(j),..,z(k)}[R_{z(m)z(m+1)} - R_{z(m+1)z(m+1)}] + P_{z(k+1)}.$$

However, since z(j) = z(k+1), this implies that $\Sigma_{m=z(j),..,z(k)}[R_{z(m)z(m+1)} - R_{z(m+1)z(m+1)}] = 0$. However, this sum can be written as:

$$\{R_{z(j)z(j+1)} - R_{z(k+1)z(k+1)}\} + \Sigma_{m=z(j+1),..,z(k)}[- R_{z(m)z(m)} + R_{z(m)z(m+1)}],$$

which, since z(j) = z(k+1) is negative by (1). This is a contradiction; thus, j=k. By definition of j, this means that z(k) = z(k+1), but by construction of the z's, this means that λ(z(k); P) = z(k). But since λ(j; P) = j if and only if $P_j = 0$, this implies that $P_{z(k)} = 0$. Thus, k satisfies (i) and (ii).

Having established that, (iii) follows by mechanical application of (4). **QED.**

Proof of Proposition 5.

Proof. *Claim.* For any m and for any equilibrium P, P $\geq [T_R]^m(\mathbf{0})$. To see this, note that P$\geq\mathbf{0}$; $T_R(q)$ is non-decreasing in q; and P=$[T_R]^m$(P), since P is a fixed point of T. Thus, P = $[T_R]^m$(P) $\geq [T_R]^m(\mathbf{0})$. This establishes the Claim.

Define the 'order' of input i in an equilibrium with price vector P as the smallest k such that λ^k(i; P) has a price of zero. Thus, any input i with $P_i = 0$ is of order zero, and any input of order greater than zero is strictly positive. Consider all of the inputs of order 1. For any such input i,

$P_i = R_{i,\,\lambda(i;\,P)} - R_{\lambda(i;\,P),\,\lambda(i;\,P)} + P_{\lambda(i;\,P)}$

$= R_{i,\,\lambda(i;\,P)} - R_{\lambda(i;\,P),\,\lambda(i;\,P)}$ since λ(i; P) is of order zero;

$= \max_{k\neq i}\{R_{i,\,k} - R_{kk}+P_k\}$ since P is a fixed point of T;

$= \max_{k\neq i}\{R_{i,\,k} - R_{kk}\}$ *a fortiori*, since $P_k\geq 0$ for all k;

$= [T_R(\mathbf{0})]_i$, where for any vector x, $[x]_i$ denotes the ith component.

Thus, the price of each input of order 1 can be expressed as the corresponding component of the vector operator T applied once to a vector of n zero prices. Similarly, if all prices of order m can be expressed as the corresponding component of T applied m times to the zero vector, then for any input i of order m+1, the following will hold.

$P_i = R_{i,\lambda(i;P)} - R_{\lambda(i;P),\lambda(i;P)} + P_{\lambda(i;P)}$

$= \max_{k\neq i}\{R_{i,k} - R_{kk} + P_k\}$ since P is a fixed point of T;

$= \max_{k\neq i}\{R_{i,k} - R_{kk} + [[T_R]^m(\mathbf{0})]_k\}$ (*a fortiori*, since $P_k \geq [[T_R]^m(\mathbf{0})]_k$ for all k by the above Claim);

$= [[T_R]^{m+1}(0)]_i$.

Thus, the reasoning can be applied to all m by induction. Observing that $[[T_R]^m(\mathbf{0})]_k = [[T_R]^r(\mathbf{0})]_k$ for all m and r greater than or equal to the order of k, and that each input is of order n-1 or less, completes the proof. **QED.**

Proof of Proposition 10.

Consider a realization of R and the price vector P that results. Holding all else constant, we may write both as a function of ϕ_i: $R(\phi_i)$ and $P(\phi_i)$. Note that $\partial R_{km}/\partial\phi_i$ takes a value of x_{km} if k = i and m ≠ i, and zero otherwise. Assume that $P(\phi_i)$ is such that there exists a neigborhood S around $P(\phi_i)$ such that for all $P' \in S$, and for any input m, $\lambda(m; P') = \lambda(m; P(\phi_i))$ (in other words, there are no tying bids). This will be true with probability 1. By Proposition 4, P_j will be affected by ϕ_i if and only if there is a chain of runner-up bidders leading from input j to input i, and $P_i > 0$. Thus, if $P_i = 0$, $\partial P_i/\partial\phi_i = 0$ and $\partial P_j/\partial\phi_i = 0$. If $P_i > 0$, then by Proposition 4, $\partial P_i/\partial\phi_i = x_{i\,\lambda(i;P)}$. Further, if $P_i > 0$, then $\partial P_j/\partial\phi_i$ takes a value of $x_{i\,\lambda(i;P)}$ if there is a chain of runner-up bidders going from j to i, and zero otherwise. Thus, if we denote by A(i, j) the set of realized values of R such that $P_i > 0$ and for some m > 0, $i = \lambda^m(j; P)$; and denote by B(i) the set of realized values of R such that $P_i > 0$, then:

$$\frac{\partial E[P_i]}{\partial \phi_i} - \frac{\partial E[P_j]}{\partial \phi_i} = \int_{B(i)\setminus A(i,j)} x_{i\lambda(i)} dG(R|\vec{\phi}) > 0,$$

where $G(R|\vec{\phi})$ is the distribution of the R matrix as a function of the vector of ϕ_i. **QED.**

A Simple Bargaining Model.

Very similar results to the bidding model can come out of a simple bargaining framework. Suppose that when an unintegrated USF_i receives its output it approaches the DSF_i with it. They bargain over price; if negotiations fail, each of the two partners may chose another firm in the sector as a potential transaction partner and begin a round of bargaining with this new partner. If this second round of negotiations fails, the input will not be sold. In both rounds of bargaining, the Nash bargaining solution is imposed. We additionally impose:

(A3) $K > 1/2$.

To see how the bargaining process works, we work backward from the last period of potential bargaining for an unintegrated USF. Suppose that USF_i's negotiations with DSF_i have broken down and it must now seek another partner to buy its input. Assume for the moment that it is the only USF seeking a partner, since all of the other USF's have successfully sold their inputs in the earlier round of bargaining; this will be confirmed as part of the equilibrium.

Suppose that USF_i bargains with DSF_j. By assumption, DSF_j (as with all of the other

DSF's) has already purchased its own tailor-made input, which gives it a cost reduction of R_{jj}. USF_i can offer it a savings of R_{ij}. Since the DSF can use only one input, the total surplus generated by this sale would be R_{ij}-R_{jj}. Since if negotiations break down, the game will simply end, the threat point for the USF is 0, but the threat point for the DSF is its status quo, R_{jj}. This all implies (with Nash bargaining) that a sale will occur if and only if $R_{ij}>R_{jj}$, and in that case the payoff to USF_i is $(R_{ij}-R_{jj})/2$, which is also the price DSF_j pays for the input. Therefore, if we allow USF_i its choice of bargaining partner, its expected revenue is:

$$\max\ \{\max_{\{j\}}\ \{(R_{ij}-R_{jj})/2\},\ 0\}. \tag{5}$$

At the same time, DSF_i has the option of trying to find a partner; since the other inputs have all been sold to other DSF's, this involves bargaining with another DSF for purchase of its input. Such a transaction would involve a surplus of R_{ji}-R_{jj} for some j (DSF_j would give up its input and receive a cost reduction of 0 instead of R_{jj}, while DSF_i would receive a cost reduction of R_{ji} instead of 0). From (1), this surplus would always be negative. Thus, such transactions will never occur, and the DSF who failed to come to an agreement in the first round of bargaining will receive a payoff of zero.

These outcomes from the second round of bargaining now form the threat points for the first round of bargaining. When USF_i bargains with DSF_i, it is clear that their threat points are given by (5) and 0 respectively[1]. Since the cost reduction that will occur if the transaction is

[1]Recall that at the time of the first round of bargaining the matrix of R_{ij}'s is known with certainty by all.

completed is R_{ii}, the surplus from the transaction is R_{ii} minus the value in (5); by (1), this is always positive, so the transaction will occur. The price that USF_i is paid for the input is:

(6)
$$\frac{1}{2}\left\{R_{ii} + \max\left\{\max_j\left\{\frac{R_{ij} - R_{jj}}{2}\right\}, 0\right\}\right\}$$

Thus, if we back up to the time at which the USF makes its decision as to whether or not to proceed with the investment, we can calculate its expected revenue. Note that if the USF has chosen maximal specialization, since $R_{ij}= 0$ for $j\neq i$, (6) takes a value of $R_{ii}/2 < 1/2$. By A3, this is less than the cost of producing the input, so we know that the unintegrated USF would never proceed with production of the input using the maximally specialized technology. Further, in calculating (6) we can ignore any DSF that has chosen the maximally specialized technology, since for such a firm $R_{jj}=1$ and so $R_{ij} - R_{jj}<0$. Thus, we restrict attention to the case of the flexible technology strategy, in which case the expected revenue to USF_i is given by:

(7)
$$\mu(\phi_i, n_\Phi) = E\left[\frac{1}{2}\left\{R_{ii} + \max\left\{\max_{j\in\Phi}\left\{\frac{R_{ij} - R_{jj}}{2}\right\}, 0\right\}\right\}\right],$$

where Φ is the set of USF's who have chosen the flexible technology strategy, n_Φ is the number of USF's in this set, and the expectation is taken with respect to the random variables x_{ij} for $j\in\Phi$. Clearly, since adding one more firm with flexible technology simply adds one more value of

R_{ij}-R_{jj} to the list from which a maximum is selected, ϕ is increasing in n_{Φ}. Thus, Proposition 6 carries over to this bargaining model. The other propositions follow similarly.

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